Hybrid Optical Elements for Dual-Focus Pickup

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ABSTRACT

Two hybrid optical elements are presented for dual-focus pickup in the digital versatile disk (DVD) system. One is a hybrid dual-focus lens and the other is a holographic regional mirror. The optical head consisting of these two hybrid optical elements can read the information recorded on two layers of DVD simultaneously. Its specifications are described. The fabrication parameters of these two hybrid optical elements are derived.

Keywords: Dual focus, optical pickup, digital versatile disk, holographic optical element, volume hologram.

1. INTRODUCTION

Because the digital versatile disk (DVD) has a large storage capacity and can be used as a multipurpose storage[1-3], it becomes a high potential product. In general, there are two layers on DVD. In order to pick up the information recorded on two layers, its optical pickup head should have the performance of dual focus. Although some types of dual focus optical pickup heads were proposed, they need an additional controlled micro-machine or an aspheric lens with holographic optical elements. It is not easy to introduce a micro-machine in a limited space or to fabricate an aspheric lens and align it with other holographic optical elements. In this presentation, two hybrid optical elements for dual-focus pickup are presented. One is a hybrid dual-focus lens and the other is a holographic regional mirror. The pickup consisting of these two hybrid optical elements can read the information on two layers of DVD simultaneously. The hybrid optical elements can be easily fabricated by the technique of shorter-wavelength construction for longer-wavelength reconstruction[4,5], and are suitable for mass-production to reduce the cost. In addition, it is easy to assemble them. The specifications of this new type of dual-focus optical pickup head are described, and the fabrication parameters for these two hybrid optical elements are derived and summarized in tables for clearness.

2. THE ARCHITECTURE OF THE DUAL-FOCUS OPTICAL PICKUP HEAD

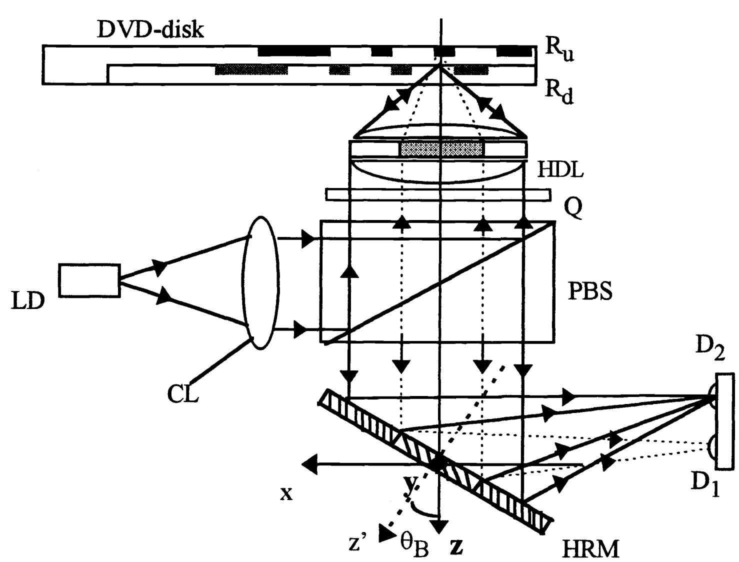

Fig. 1 The architecture of this new type of the dual-focus pickup head.

The architecture of this new type of dual-focus optical pickup head consisting of these two hybrid optical elements is shown in Fig. 1. A linearly, vertically polarized light (i.e., s-polarization) coming from a laser diode LD is collimated by a collimating lens CL, and is reflected with nearly 100% reflectance by a polarization beam-splitter PBS. Next, the light is circularly polarized after the quarter-wave plate Q, and is divided into two parts by a hybrid dual-focus lens HDL: the inner part and the outer part. They are focused on the upper and lower layers of DVD, respectively. Consequently, the reflected lights with the information propagate along their original paths and pass through the corresponding regions of HDL as they passed before. And they are re-collimated and become linearly horizontal by polarized lights (i.e., p-polarization) after their second passage through HDL and Q. Then they pass through PBS directly with nearly 100% transmittance and arrive the holographic regional mirror HRM. HRM consists of two different holographic mirrors: the inner holographic mirror HM_i and the outer holographic mirror HM_o. They have the same optical axis and Bragg angle, but have different diffraction angles. HM_i and HM_o will diffract the lights coming from the upper and lower layers to detectors D_1 and D_2, respectively, and the information recorded on two layers is read simultaneously.

3. HYBRID OPTICAL ELEMENTS

(a) HYBRID DUAL-FOCUS LENS

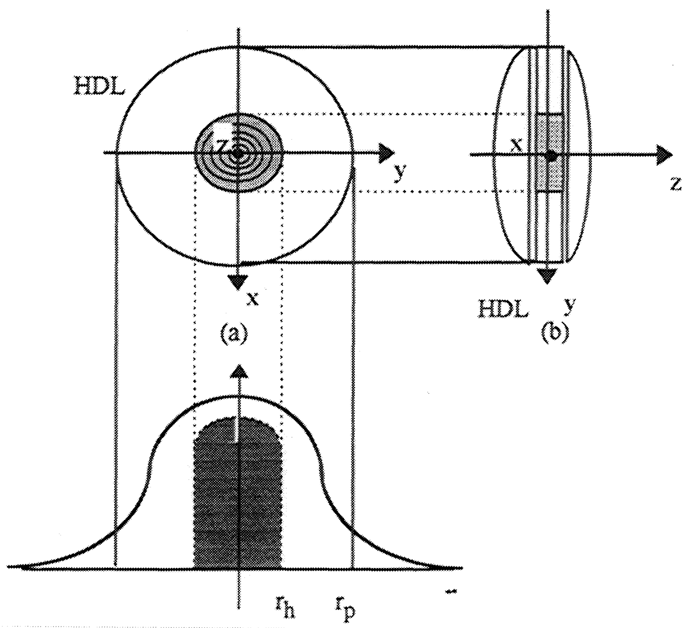

Fig. 2 The configuration and performance of the hybrid dual-focus lens.

The configuration of this hybrid dual-focus lens HDL is depicted in Fig. 2. It consists of two plano-convex lenses and a small holographic lens HL, which is cemented between the plane surfaces of these two plano-convex lenses with the same optical axis as shown in Fig. 2(b). Its two focal lengths of HDL for the upper and the lower layers are f_u and f_d, and the focal lengths of these two plano-convex lenses are f_1 and f_2, respectively. To meet with the requirements for reading the information recorded on two layers simultaneously, the thickness d of a layer should be equal to the difference between f_u and f_d. Then the focal length f_h of HL should be satisfied the following equations:

$$\frac{1}{f_d} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_h}, \tag{1}$$

and

$$\frac{1}{f_u} = \frac{1}{f_1} + \frac{1}{f_2}. \tag{2}$$

From Eqs. (1) and (2), and the relation $d = f_u - f_d$, we have

$$f_h = \frac{f_u f_d}{d}. \tag{3}$$

The diffraction properties of HL depend on the geometries of recording and reconstruction. The relevant coordinates (R_q, β_q) are the positions of the point sources; where R_q (q = o, r, c, i) are the distances from the point sources of (object, reference, reconstruction, image) to the center of hologram. The necessary conditions for an efficient, aberration-free holographic lens are given as[6]

$$\left.\begin{aligned} \frac{1}{R_o} &= a\frac{1}{R_i} + b\frac{1}{R_c}, \\ \frac{1}{R_r} &= a\frac{1}{R_c} + b\frac{1}{R_i}, \end{aligned}\right\} \tag{4}$$

and

$$\left.\begin{aligned} \sin\beta_o &= a\sin\beta_i + b\sin\beta_c, \\ \sin\beta_r &= a\sin\beta_c + b\sin\beta_i, \end{aligned}\right\} \tag{5}$$

where $a \equiv [(\mu+1)/2\mu] + \Delta$, $b \equiv [(\mu-1)/2\mu] + \Delta$, $\Delta = [(\mu^2-1)\sin^2\beta_i/(16n^2\mu^2)] + [(\sin^4\beta_i)/(32n^4)]$, μ is the ratio between the reconstruction and recording wavelengths, and n is the refractive index of the recording material. Among these parameters, λ_c, R_i, R_c, β_i, β_c and f_h can be obtained from the specifications of the optical pickup head, the fabrication parameters of HL can be derived with Eqs. (4) and (5).

Next, the radius r_h and the diffraction efficiency η of HL should be considered. Because the incident light has a Gaussian distribution as shown in Fig. 2, its normalized intensity profile can be expressed in polar coordinates as follows:

$$U(r) = \exp\{-2h^2 r^2\}, \tag{6}$$

where h is a Gaussian truncation coefficient. The light intensities being incident on the upper and lower layers are

$$I_u = \eta\, U(r_h), \tag{7}$$

and

$$Id = U(r_p) - U(r_h), \tag{8}$$

respectively; where r_p is the radius of the plano-convex lens. If the reflectances of the upper and lower layers are R_u and R_d, then the light intensities of I_u and Id will become I_u' and I_d', respectively, after the second passage through HDL. And I_u' and I_d' can be written as

$$I_u' = \eta^2 U(r_h)\, R_u, \tag{9}$$

and

$$I_d' = [U(r_p) - U(r_h)]\, R_d. \tag{10}$$

For good signal qualities, the relation $I_u' = I_d'$ should be satisfied, that is,

$$\eta^2 U(r_h)\, R_u = [U(r_p) - U(r_h)]\, R_d. \tag{11}$$

(b) HOLOGRAPHIC REGIONAL MIRROR

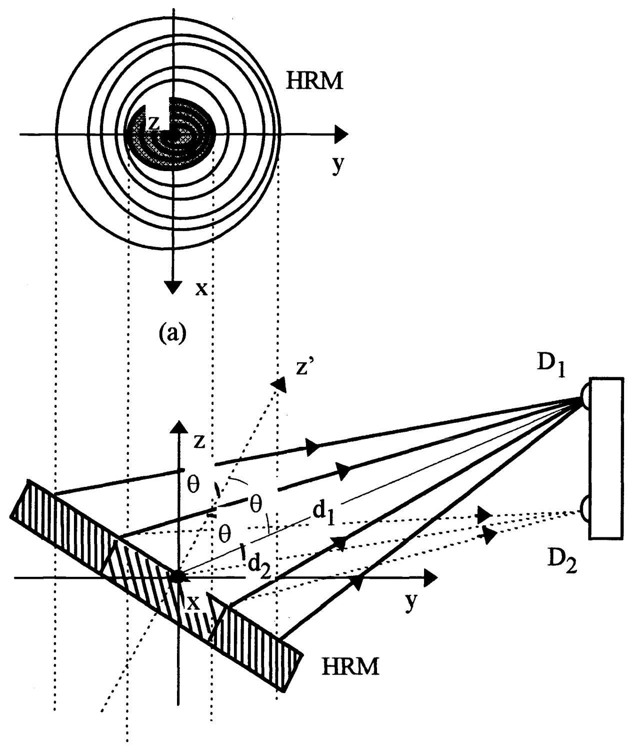

Fig. 3 The configuration and performance of the holographic regional mirror.

The configuration and performance of the holographic regional mirror HRM are shown in Fig 3. It consists of the inner holographic mirror HM_i and the outer holographic mirror HM_o, which diffract the reflected light coming from the upper and the lower layers to detectors D_1 and D_2, respectively. HM_i and HM_o have the collimated reconstruction lights at the same optical axis and Bragg angle $\theta_B = 45°$, but have different diffraction angles. And their fabrication parameters can be obtained similarly with Eqs. (4) and (5).

4. SPECIFICATIONS AND FABRICATION

To get compatible with common DVD systems, the specifications of this new type of dual-focus optical pickup head are carefully chosen and summarized in Table. 1. The holographic lens and the holographic regional mirror can be fabricated with the shorter recording technique of shorter-wavelength construction for longer-wavelength reconstruction[4,5]. In our experiments, they are fabricated with self-made dichromated gelatin (DCG) and a He-Cd laser of wavelength 441.6 nm.

Under these conditions and above specifications, their fabrication parameters can be calculated based on above Eqs. (1)-(11), and are summarized in Table 2.

5. DISCUSSION

The diffraction efficiencies of the holographic lens and the holographic regional mirror depend on the exposure energy. Before we fabricated them, their corresponding diffraction efficiency versus exposure energy were measured. According to the results, the optional exposure energy can be chosen for the desired diffraction efficiencies. If these elements are fabricated with photoresist, then the hologram copying technique can be used for mass-production and reduce the cost.

6. CONCLUSION

Two hybrid optical elements for dual-focus optical pickup head in the digital versatile disk system are presented. This pickup head can read the information on two layers of DVD simultaneously. The specifications of this new type pickup are so chosen carefully that it can be compatible with the common DVD systems. The fabrication parameters of the holographic lens and the holographic regional mirror are derived, and they are fabricated.

ACKNOWLEDGMENT

This study was supported in part by the National Science Council, R.O.C., under contract number NSC86-2215-E-009-007.

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HDL	NA=0.6 λr=635nm
f_u	5.6mm
f_d	5mm
f_h	46.7mm
A	7.5mm
h	$1mm^{-1}$
r_p	3.5mm
r_h	0.7976mm
R_u	0.9
R_d	0.8
ΔD	3.6mm
L_y	20mm
d_1	20mm
d_2	20.7mm
r_i	0.78mm
r_o	3.5mm

Table. 1 Specifications of this new type of hybrid dual-focus optical pickup head.

(mm)	R_i (635nm)	R_r (635nm)	R_c (441.6nm)	R_o (441.6nm)	β_i (635nm)	β_r (635nm)	β_c (441.6nm)	β_o (441.6nm)
DHL	46.7	∞	55	306	0	0	0	0
HM_o	20	∞	125	23.81	30^o	45^o	42.3^o	32^o
HM_i	20.6	∞	129.4	24.64	40^o	45^o	44^o	40.8^o

Tab. 2 Fabrication parameters of the holographic lens and the holographic regional mirrors.